



Using Cost-Risk to Connect Cost Estimating and EVM

**Presentation to
PM Challenge 2007**

Down to Business Track

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Outline

- **NASA Cost Initiatives: Emphasis on identifying, quantifying and managing cost-risk**
- **OMB's Capital Planning Guide**
- **Point Estimates vs Range Estimates**
- **Cost-risk assessment and analysis**
 - Cost estimating relationship risk
 - Cost model input parameter/driver risk
 - Key system/subsystem/WBS element characteristic risk
 - Correlation
- **Connecting Cost Estimating and EVM**
- **Risk Management Metric**



NASA Cost Initiatives

- Cost Initiatives motivated by congressional interest (negative 2004 GAO NASA Cost Estimating Report) and President's Commission Report on Space Exploration
- Initiatives to improve Agency cost estimating are documented in the new NASA Cost Estimating Handbook (www.ceh.nasa.gov) which is tied closely to NPR 7120.5D
- The initiatives include:
 - The use of cost risk analysis to quantify uncertainty
 - Better cost data collection using a Cost Analysis Data Requirement (CADRe)
 - A corporate data base of CADRes – the One NASA Cost Engineering (ONCE) database





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■ OMB Focus on Risk

- *Without the knowledge of the risks* involved *managers* at all levels—Agency, Office of Management and Budget (OMB) and Congress — *cannot make the best decisions* for the allocation of resources among the competing investments
- *Project managers* when developing the cost, schedule and performance goals on developmental projects with significant risk *must*, therefore, *provide* the agency Executive Review Committee with *risk adjusted, most likely cost, schedule and performance goals*



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- **Risks**for each WBS element should **be identified, analyzed, and quantified** in terms of potential cost to the program
 - **Risk identification** involves analyzing program areas and critical technical elements to **identify and document the associated risk**
 - **Risk analysis** involves examining each risk issue to determine the **probability of the risk occurring**
 - **Risk quantification** results in the **cost, schedule and technical consequences** if the risk occurs



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- **Program (Project for NASA) Risk-Adjusted Budget (PRB)**
 - The **cost of the risk occurrence** is **added to the BAC** and the result of this analysis is a **risk adjusted budget**
 - The program's (investment's) **risk-adjusted budget establishes the baseline** for reporting to OMB on program performance
 - The appropriate agency official must ensure the **PRB is justified based on risk**, and that the **agency will fund the program at that level**



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- ***Risk management*** begins with evaluating the ***WBS*** for ***cost, schedule and technical risk***
- Program budget, expected outcomes and ***cost/schedule performance measurements*** are ***integrated with risk management***



Point vs Range Estimates

- Being precise about point estimates is next to impossible
- However, range estimating is eminently possible
- Cost-risk quantification enables the process of developing range estimating
- *Projects expected to do range estimating in their CADRe Part C LCCE*



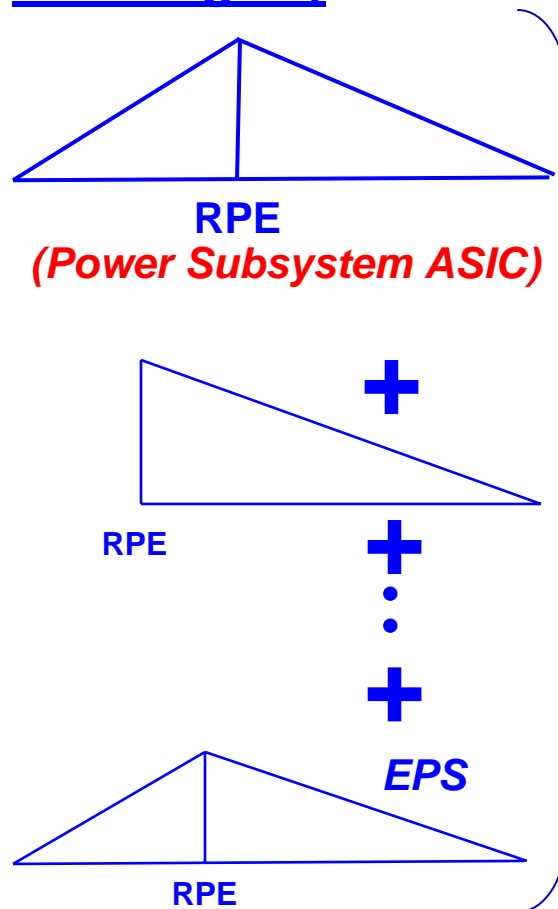
Cost-Risk Assessment & Analysis

- **Assessment**
 1. **Cost model uncertainty** (parametric estimating only)
 - “Scatter” in data base used to derive estimating equation
 2. **Input parameter uncertainty** (parametric estimating only)
 - Spread in estimating input parameter values
 3. **Risk-Driven Key Element Characteristic (KEC) uncertainty**
 - Level of TRL, New Design, Schedule, etc., effects on
 - Key Engineering Parameter Performance
 - Key Management Characteristics
 - Key System Engineering Characteristics
 - Evaluated using techniques such as the Relative Risk Weighting (RRW) process
 4. **Correlation uncertainty**
 - Correlation in movement of WBS element costs
- **Analysis**
 - Convolve all distributions for “S”-curve (CDF)



Cost-Risk Analysis: Convolution

CORRELATED WBS ELEMENT COST DISTRIBUTIONS (note: not necessarily all triangles):

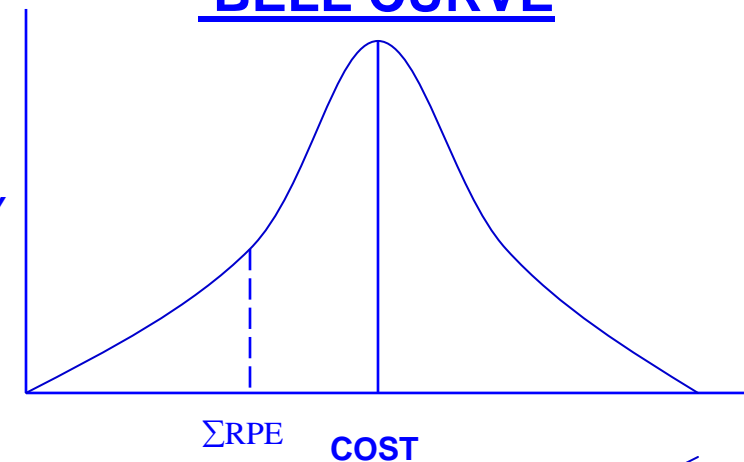


CER,
Parameter Input,
and KEC's
Cost-Risk
Distributions on
Lower Level
WBS Elements

PROBABILITY
DENSITY

=

SUMMARY COST DISTRIBUTIONS: BELL CURVE



100

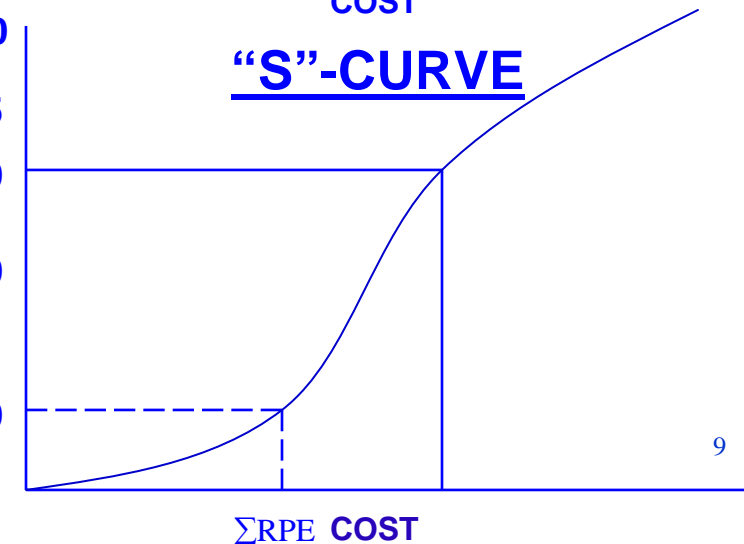
85

70

50

20

"S"-CURVE





-
- ```

graph TD
 MHR([Medium & High-Risks])
 MHR --> A[Assess Data For Model & Database Updates (CADRe & ONCE)]
 A --> B[Build/Update Reqmts-Function-WBS Matrix (CADRe)]
 B --> C[Develop Ref Point Cost & Schedule Estimate]
 C --> D([Identify & Assess WBS Element Risk])
 D --> E[Quantify Risk into Cost /Schedule Impacts]
 E --> F[Develop CPR & CADRe Cost RFP DRDs]
 F --> G([Do EVM, "S"-curve, schedule risk critical path analyses, etc.])
 G --> H[Update LCCE (CADRe) & Cost / Sched-Risk Assessment]
 H --> I[Compile End-of-Contract Cost-Risk Data for Evaluation & Analysis]
 I --> A
 D -.-> A

```



# **EVM Working Group Draft**

## **Contract Performance Report (CPR) DRD Template**

**([www.ceh.nasa.gov](http://www.ceh.nasa.gov))**

Earned value performance measurement data for government-identified medium and high-risk WBS elements (see list below), **if available and appropriate**, shall be reported on Formats 1 & 2 of the monthly CPR until such time as both government project management and the contractor agree that they no longer represent medium or high risks

**Power Subsystem ASIC; Solar Power Converter; Pointing & Control System  
Laser Amplifier/Transmitter; Laser Transmit Antenna; Microwave Receive Antenna;  
Laser Receive Antenna; Tracking & Control System; Laser Conditioning Receiver; Laser  
Rectifier/Converter; Flywheel Storage System**

This reporting on medium and high-risk WBS elements shall be at a **level that is adequately sensitive** to performance measurement indicators to ensure earliest identification of cost and schedule problems caused by the source risks (e.g., level 5, 6, or 7 or just above control account level)

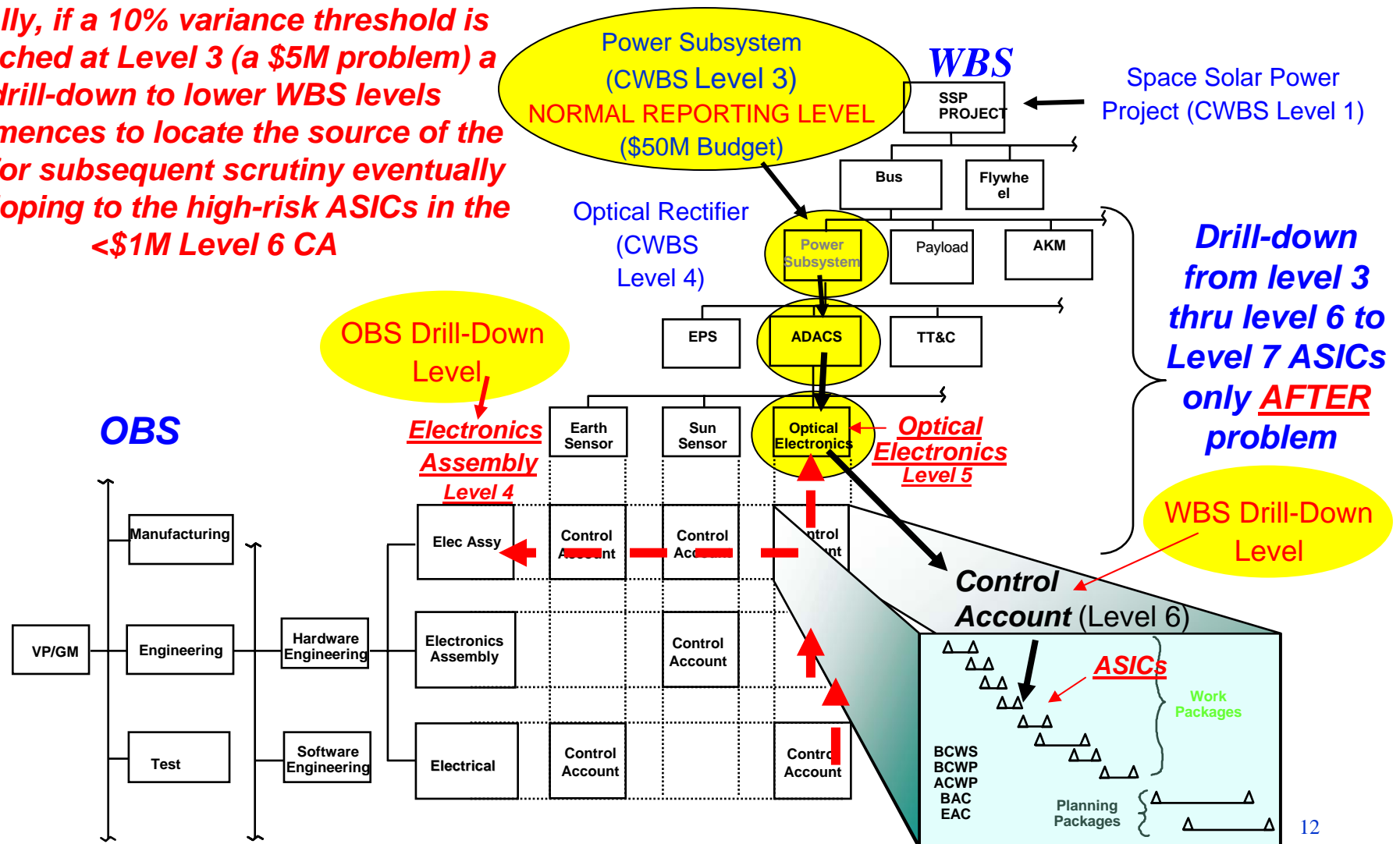
**Narrative variance analysis is not required for this level of medium and high-risk WBS elements**

The contractor shall identify all known medium and high-risk WBS elements **specific to his design**, if not provided in the list above, and report their performance measurement on CPR Formats 1 & 2

# Traditional CPR Level 3 Reporting

## 10% Variance Reporting

***Normally, if a 10% variance threshold is breached at Level 3 (a \$5M problem) a drill-down to lower WBS levels commences to locate the source of the risk for subsequent scrutiny eventually developing to the high-risk ASICs in the <\$1M Level 6 CA***

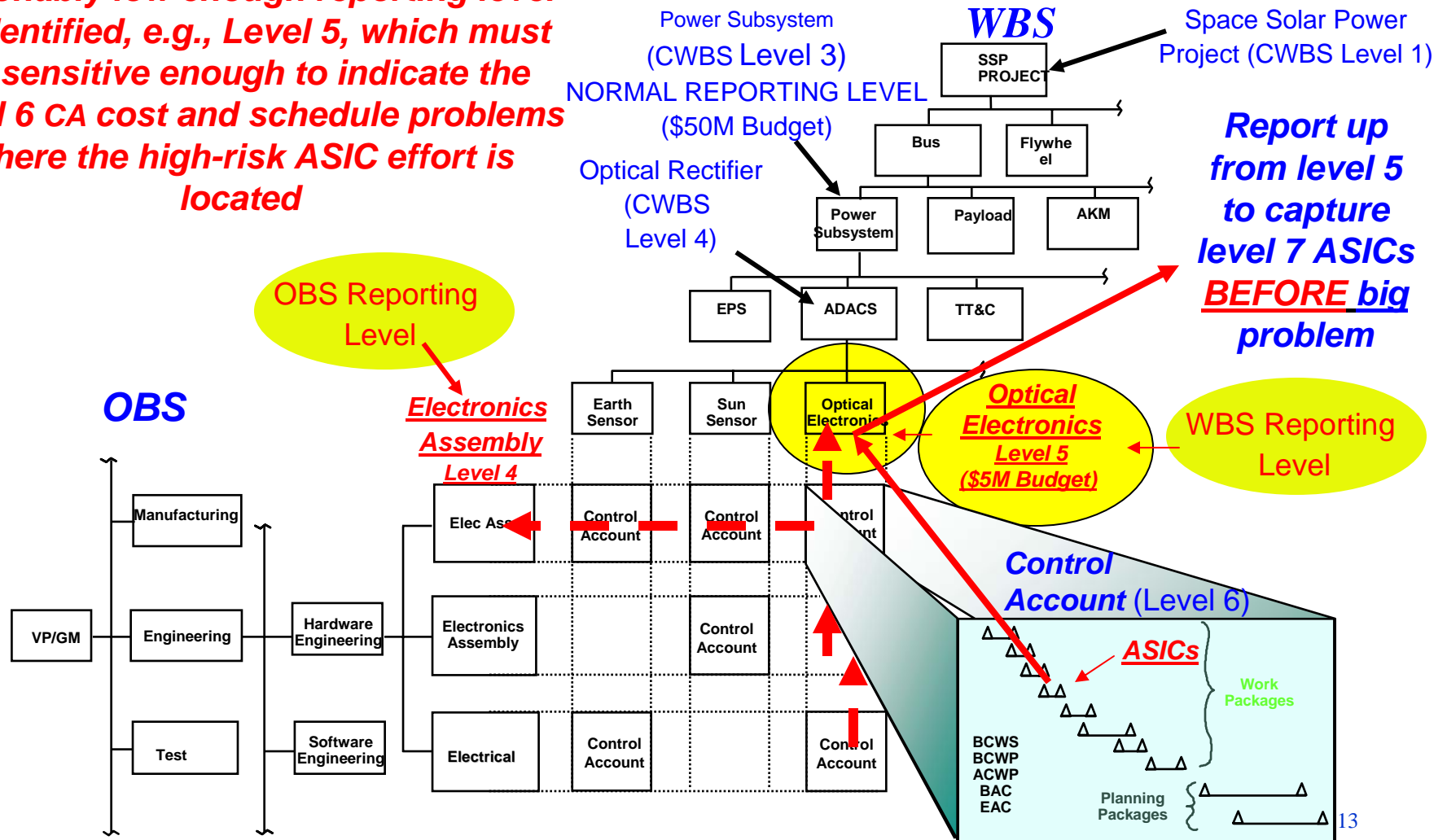




# Med/High Risk Reporting

## High-Risk No-Threshold Variance Reporting<sup>3</sup>

*A reasonably low enough reporting level is identified, e.g., Level 5, which must be sensitive enough to indicate the Level 6 CA cost and schedule problems where the high-risk ASIC effort is located*



<sup>3</sup>Until risk is no longer a threat or is retired



# HIGH RISK CONTROL ACCOUNT

## with ASIC MITIGATION PLAN WORK PACKAGE

High-risk  
WBS element

Risk handling  
work package

|                                                           |                              |                |      |            |         | EV Techniques                        |         |         |         | 0/100, 50/50, Units Complete, % Complete, Milestones |  |
|-----------------------------------------------------------|------------------------------|----------------|------|------------|---------|--------------------------------------|---------|---------|---------|------------------------------------------------------|--|
| CONTROL ACCT. TITLE: <b>Optical Frequency Demodulator</b> |                              |                |      |            |         | CONTROL ACCOUNT MANAGER: Joe Hamaker |         |         |         |                                                      |  |
| BUDGET: \$10,000                                          |                              |                |      |            |         |                                      |         |         |         |                                                      |  |
| TIER I MILESTONE                                          |                              |                |      | ⬆          |         |                                      |         |         | ⬆       |                                                      |  |
| WP#                                                       | WORK DESCRIPTION             | EV METHOD      |      | MONTH 1    | MONTH 2 | MONTH 3                              | MONTH 4 | MONTH 5 | MONTH 6 | TOTAL BAC                                            |  |
| 1                                                         | <b>Procure Casing</b>        | 0/100          | BCWS |            |         |                                      |         | 1,500   |         | 1,500                                                |  |
|                                                           |                              |                | BCWP |            |         |                                      |         | 1,500   |         |                                                      |  |
| 2                                                         | <b>Optical Freq Receiver</b> | 50/50          | BCWS |            |         | 500                                  | 500     |         |         | 1,000                                                |  |
|                                                           |                              |                | BCWP |            |         | 500                                  |         | 500     |         |                                                      |  |
| 3                                                         | <b>OPT-RF ASICs</b>          | units complete | BCWS | 600        | 600     | 600                                  | 600     | 600     |         | 3,000                                                |  |
|                                                           |                              |                | BCWP | 600        | 600     | -                                    | 1,200   | 600     |         |                                                      |  |
|                                                           |                              |                | BCWS |            | 50      | 50                                   | 50      |         |         | 150                                                  |  |
| 4                                                         | <b>ASIC MITIGATION PLAN</b>  | milestone      | BCWP |            | 1       | 2                                    | 3       |         |         |                                                      |  |
|                                                           |                              |                | BCWS |            | 50      | -                                    | 50      | 50      |         |                                                      |  |
| 5                                                         | <b>Integration</b>           | % complete     | BCWS |            |         |                                      | 500     | 500     | 500     | 1,500                                                |  |
|                                                           |                              |                | BCWP |            |         |                                      | -       | 300     | 1,200   |                                                      |  |
| TOTAL CONTROL ACCOUNT PLAN                                |                              |                | BCWS | 600        | 650     | 1,150                                | 1,650   | 2,600   | 500     | 7,150                                                |  |
|                                                           |                              |                | BCWP | 600        | 650     | 500                                  | 1,250   | 2,950   | 1,200   | 7,150                                                |  |
| <b>Schedule Variance</b>                                  |                              |                |      | month      | 0       | 0                                    | -650    | -400    | 350     | 700                                                  |  |
|                                                           |                              |                |      | cumulative | 0       | 0                                    | -650    | -1,050  | -700    | 0                                                    |  |
| <b>Actual Costs</b>                                       |                              |                |      | 700        | 1,700   | 1,300                                | 2,300   | 5,200   | 2,100   | 13,300                                               |  |
| <b>Cost Variance</b>                                      |                              |                |      | month      | -100    | -1,050                               | -800    | -1,050  | -2,250  | -900                                                 |  |
|                                                           |                              |                |      | cumulative | -100    | -1,150                               | -1,950  | -3,000  | -5,250  | -6,150                                               |  |

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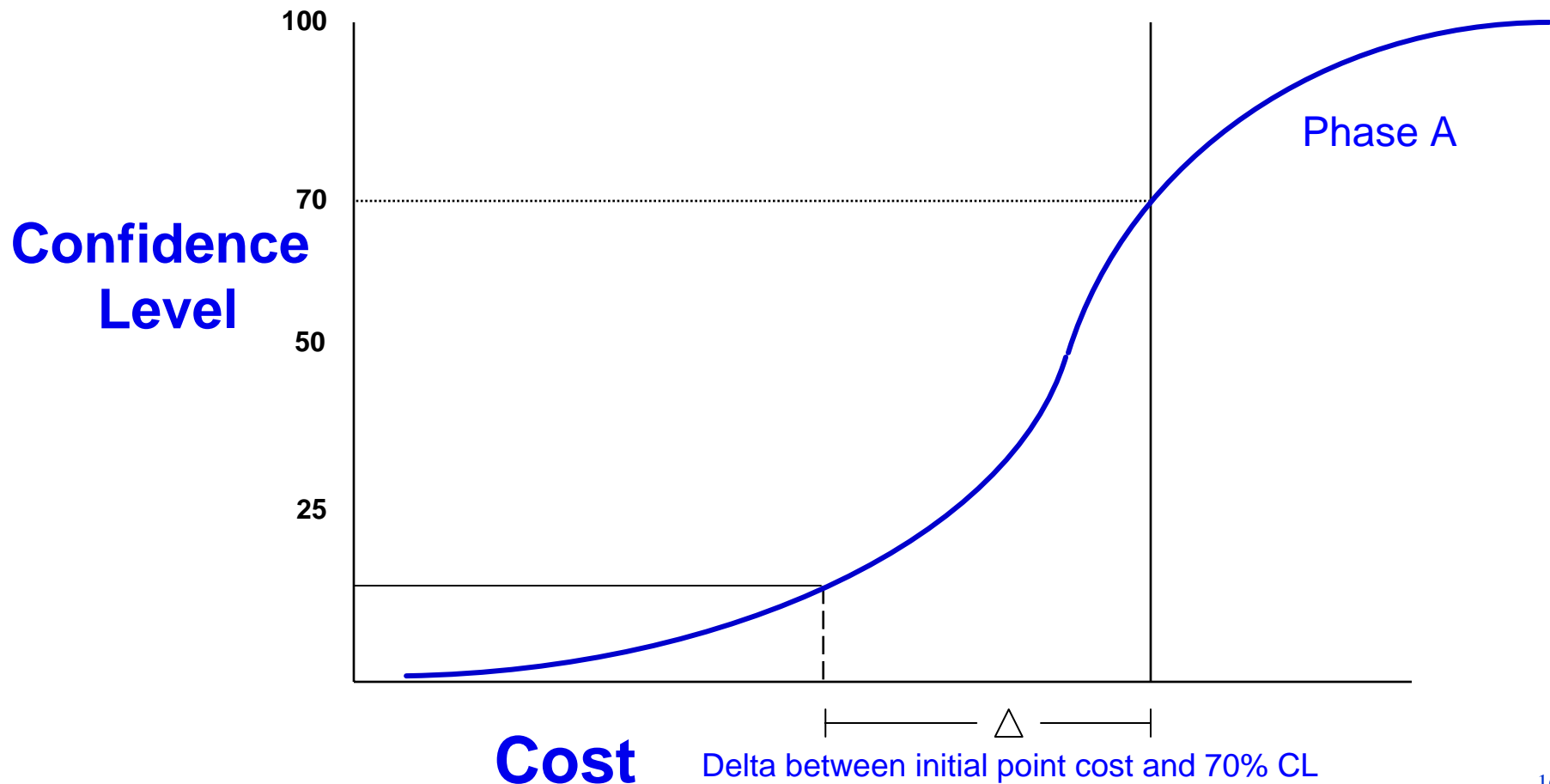
# **Risk Management Metric**

**Measuring the effect of cost-risk  
management using S-curves**





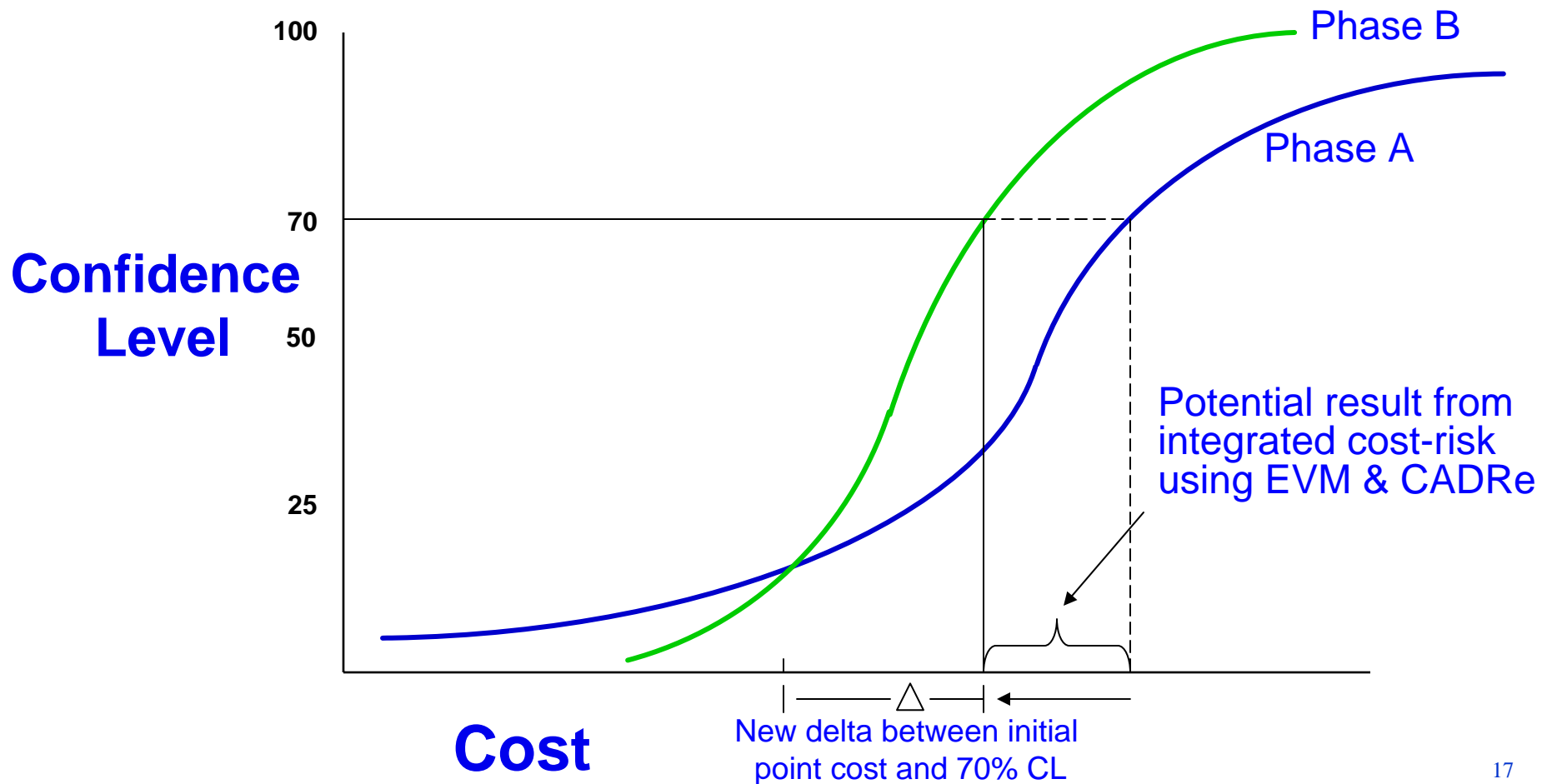
# S-Curve Improvement Metric Beginning-of-Phase A S-Curve (Starting Point for Risk Management)





# S-Curve Improvement Metric (Ideal)

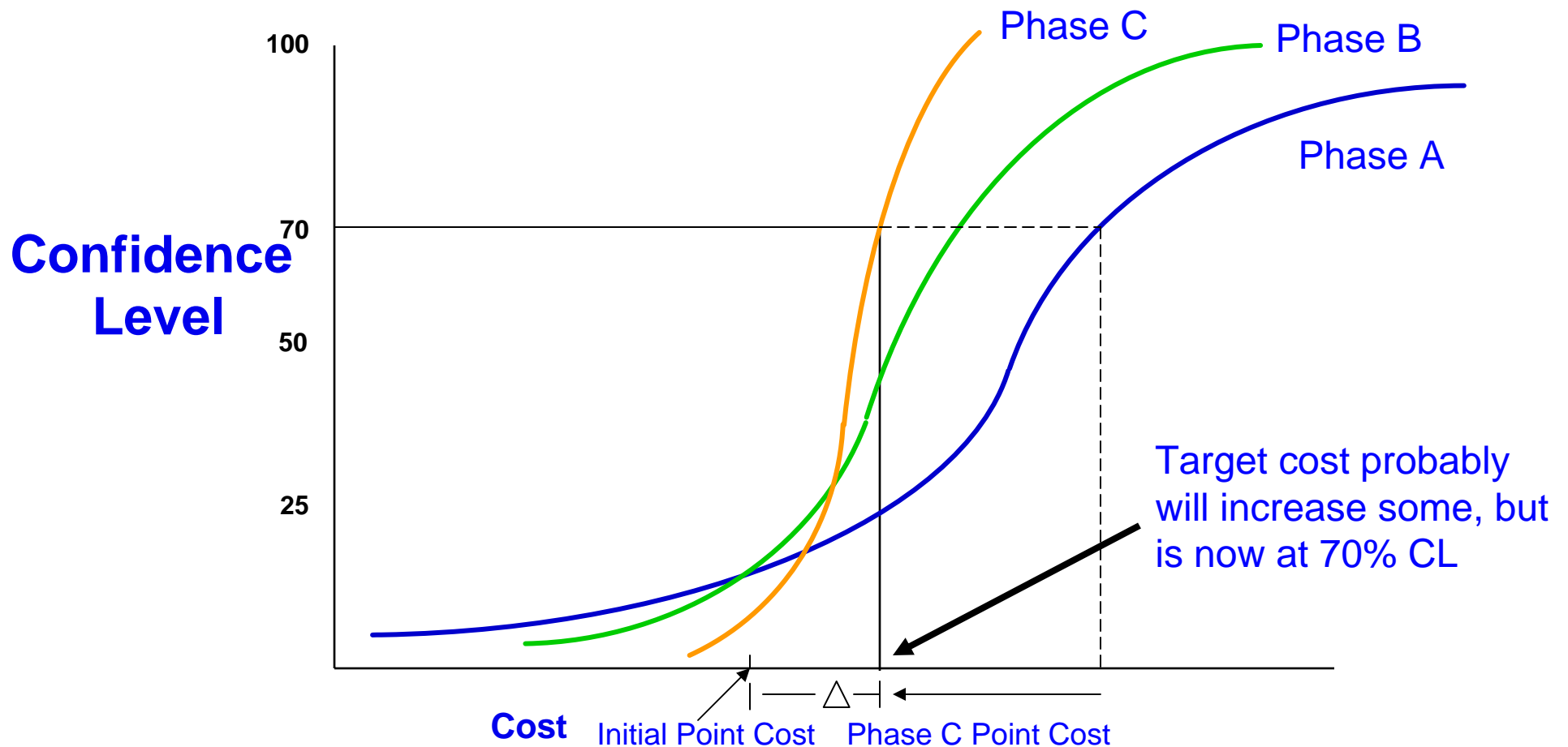
## Beginning-of-Phase B S-Curve (RM occurred from Phase A to Phase B)





# S-Curve Improvement Metric (Ideal)

## Beginning-of-Phase C S-Curve (RM occurred from Phase B to Phase C)

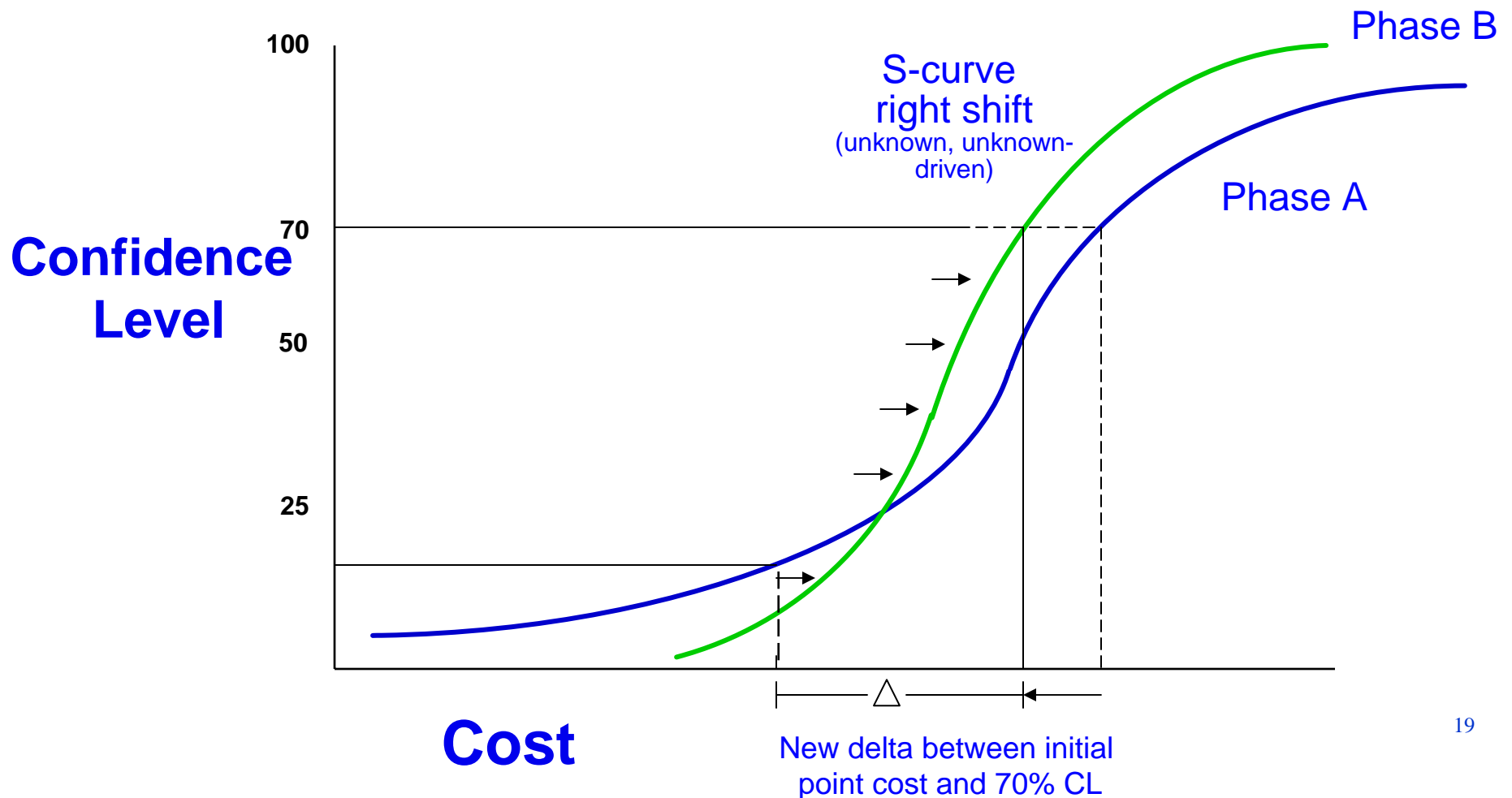




# S-Curve Metric (Realistic?)

## Phase B S-Curve

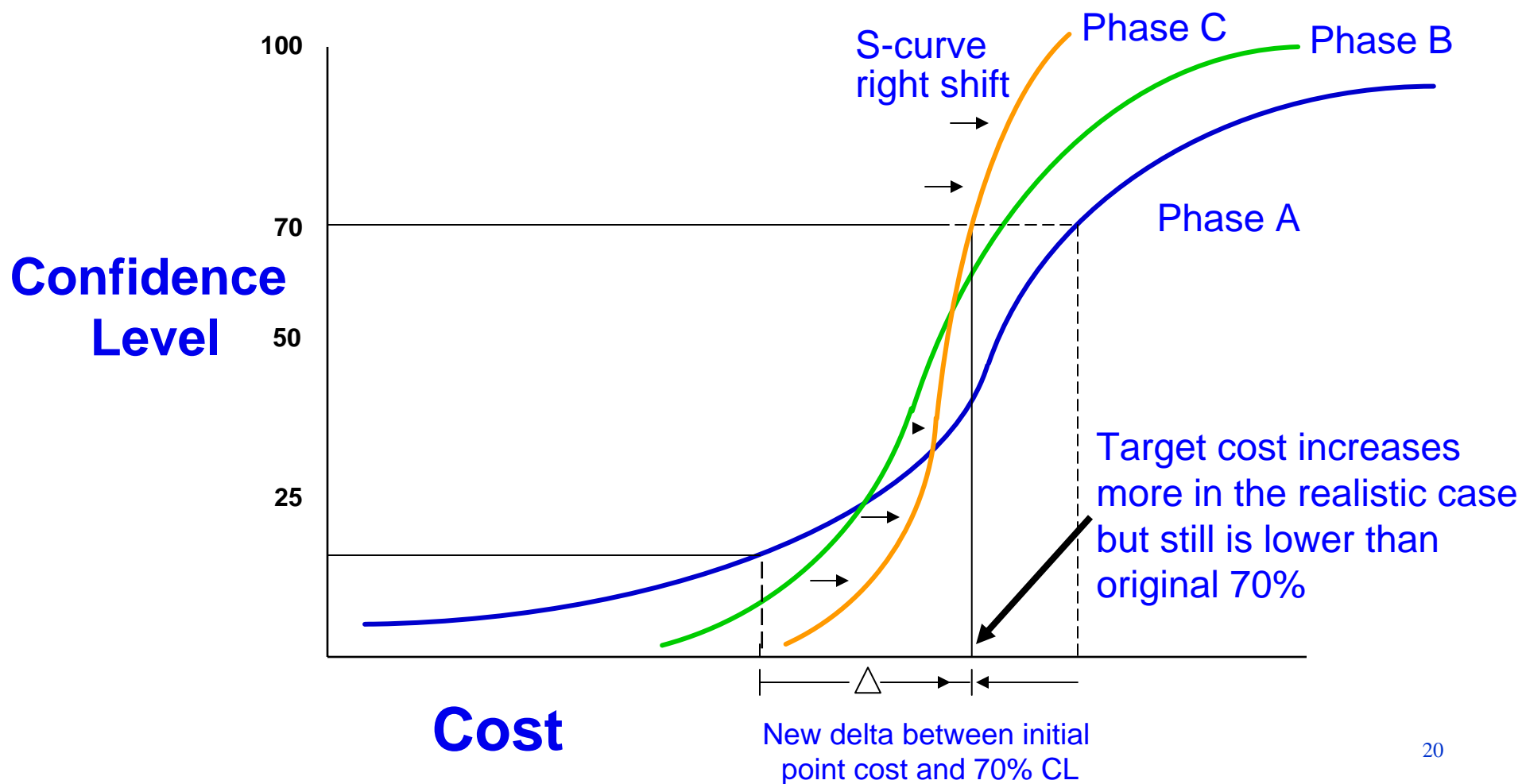
### (RM from Phase A to Phase B)





# S-Curve Improvement Metric (Realistic?)

## Phase B S-Curve (RM from Phase A to Phase B)





# Why Do Cost-Risk Analysis?

*“....these uncertainties exist whether or not we do the analysis”*

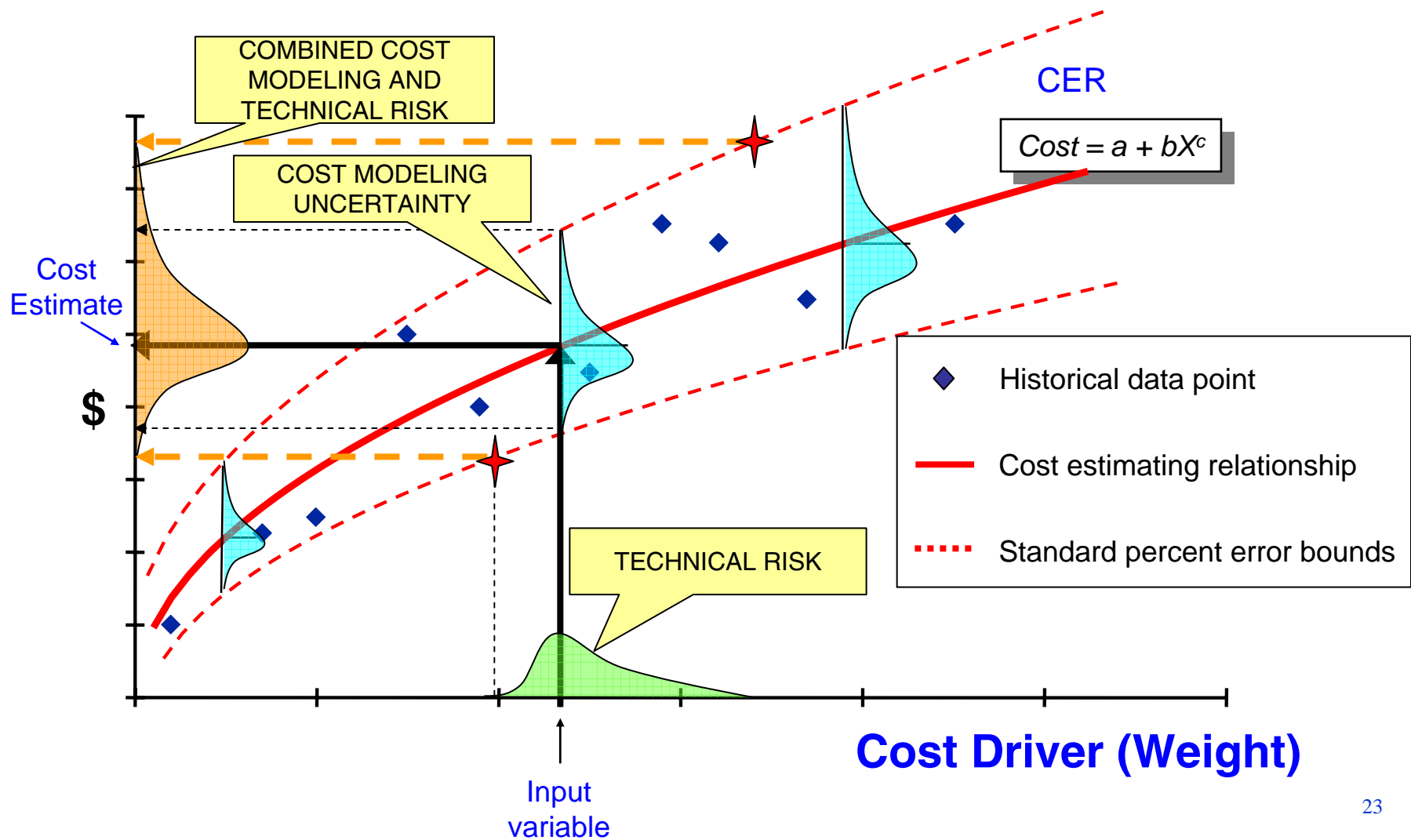
*Statement on risk analysis made by Dr. George Apostolakis, MIT Professor of Risk Management & expert in nuclear power probability risk analysis (PRA), speaking at Dec 05 NASA Risk Management Conference, Orlando, FL.*



# BACKUPS



# Cost Model and Input Parameter Uncertainty Cost Quantification







# Key WBS Element Characteristic Uncertainty

- **Key Engineering Performance Parameters<sup>1</sup> (KEPPs) for new electronic component for a S/C**
  - Dynamic load resistance
  - Operating voltage
  - Power regulation
    - ASIC
  - Radiation resistance
  - Emissivity
  - Component mass
  - Operating temperature range
  - Operating efficiency
  - etc.



# Key WBS Element Characteristic Uncertainty

- **Key Management Characteristics (KMCs)**
  - Experience of personnel
  - Risk management effort levels
  - Earned Value Management implementation level
  - Management structure (IPT, functional, matrix, etc.)
  - etc.



# Key WBS Element Characteristic Uncertainty

- **Key System Engineering Characteristics (KSECs)**
  - Level of system engineering expertise
  - Percentage of system engineering performed early
  - Tools used for requirement/function allocation
  - Logistics considerations
  - Planning, monitoring, measuring, B/C studies, etc.
  - Percentage of system engineering performed during effort
  - etc.



# Correlation

- Dr. Stephen Book (MCR) plotted the theoretical underestimation of percent total cost standard deviation (y-axis) when correlation (x-axis) is assumed to be zero rather than its true value,  $\rho$ .
  - In cost estimates we would underestimate % SD ~60%-80% if we ignored correlation and it was actually 0.2

